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Electrical Circuit Troubleshooting

APTA Bus Technical Maintenance Committee Webinar

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Welcome

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Housekeeping

- This webinar will be **recorded** and made available on APTA's website
- All attendee phone lines are **muted**
- To ask a question, use the **Questions panel**; questions will be answered at the **end** of the presentations



A screenshot of a GoToWebinar interface. The top window is titled 'Audio' and shows settings for 'Telephone' (selected) and 'Mic & Speakers'. It displays dialing information: 'Dial: +1 (914) 614-3429', 'Access Code: 871-482-194', and 'Audio PIN: 9'. A red box highlights the instruction: 'If you're already on the call, press #9# now.' Below this is a link for '(and additional numbers ...)' and another link for 'Problem dialing in?'. The bottom window is titled 'Questions' and contains a large text input area with the placeholder text '[Enter a question for staff]' and a 'Send' button. A red rounded rectangle highlights the entire 'Questions' panel. At the bottom of the interface, it says 'Webinar Now', 'Webinar ID: 153-465-475', and the 'GoToWebinar' logo.

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Objectives

Attendees will learn about:

1. *Performing circuit testing to identify open circuit*
2. *Performing a voltage drop test to identify high resistance conditions*
3. *Identifying faulty ground conditions*

Introduction

The most common electrical circuit faults you will encounter when working on bus electrical systems are: open circuits; short circuits; and high resistance.

Open Circuit - any break (open) in the current path of a series circuit makes the entire circuit inoperative. In a parallel circuit, only the branch effected by the open is inoperative.

Short Circuit - this can be a short-to-ground or short-to-voltage. This may cause a component to continuously operate regardless of switch position, or a fuse to repeatedly blow, depending on the fault.

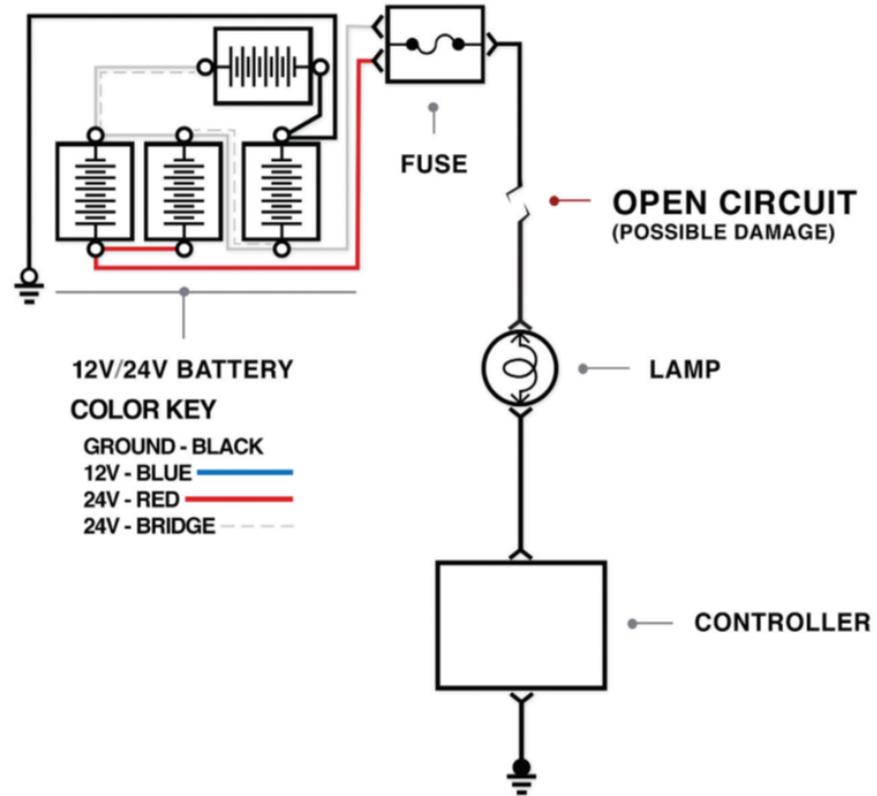
Unwanted Resistance - the load device does not receive the proper voltage/current to perform work and may operate sluggishly, dim, or not operate at all.

Open Circuits

A circuit is said to be OPEN when a break exists in the path of current flow. Although an open occurs when a switch is used to de-energize a circuit, an open may also develop accidentally. To restore a circuit to proper operation, the open must be located and repairs made.

In circuits with an open check for:

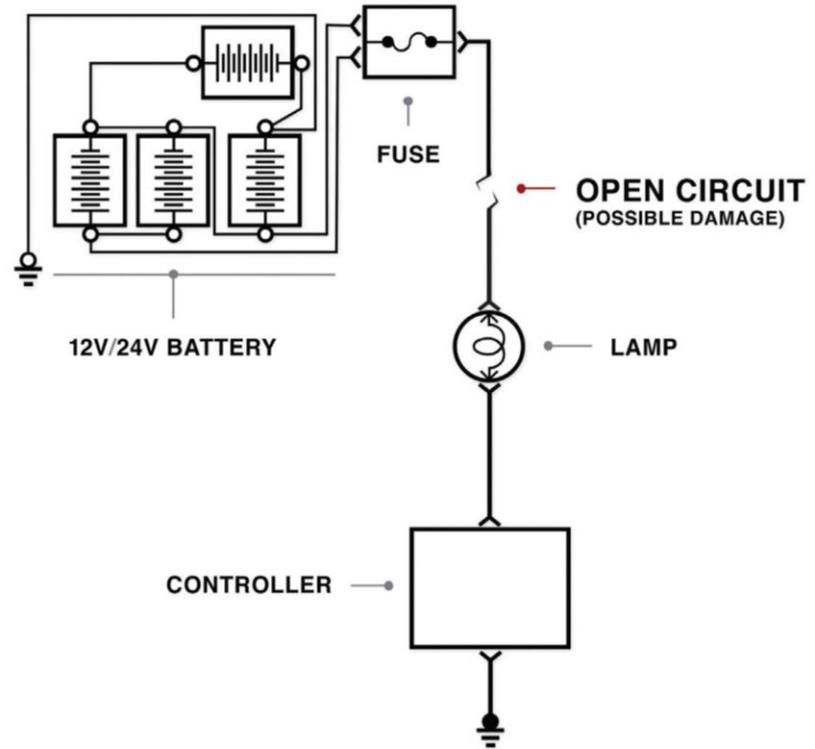
- Loose connectors, pins and terminals
- Broken grounds
- Physical damage to the harness or vehicle



Troubleshooting an Open Circuit

Find the open by measuring voltage:

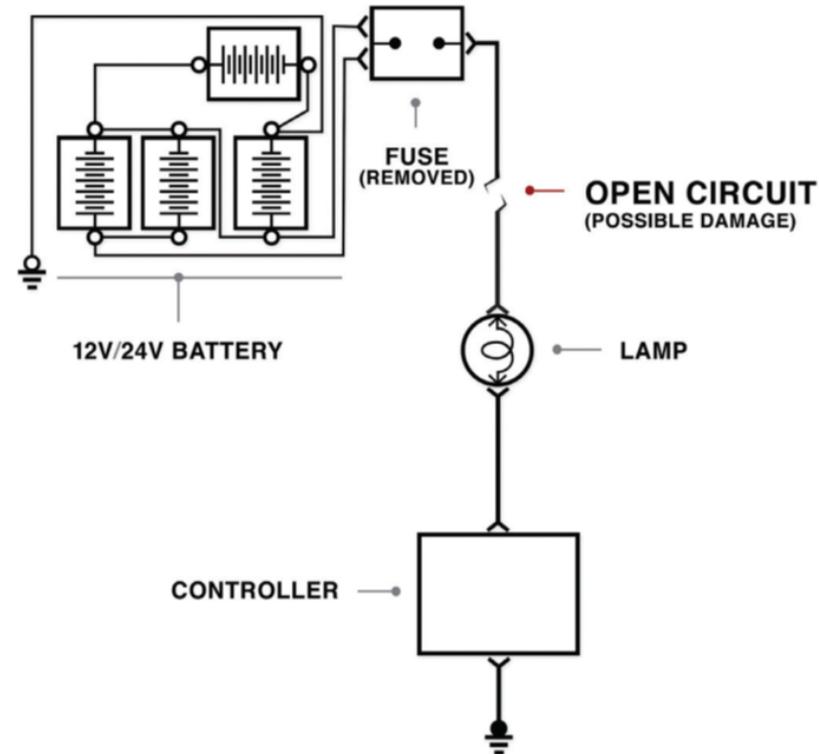
1. Measure voltage level at the fuse.
2. Work your way point by point toward the circuit ground.
3. Continue until you find a point where voltage is no longer present. The open is between the last two measured points.



Troubleshooting an Open Circuit

The best method for diagnosing an open circuit is by measuring voltage. When that is not possible, measure resistance following the steps below.

1. Remove the circuit fuse.
2. Measure resistance between circuit ground and a circuit point closest to fuse; at this point you should measure OL or very high resistance.
3. Work your way toward ground, point by point. Continue until you find a point where continuity is present. The open is between the last two measured points. From this point you may have to further isolate using the method above.



Short Circuits

A short circuit is a fault that creates an unwanted path between two parts of a circuit, or a short can bridge two circuits together.

A short can be:

- An unwanted path between part of a circuit and ground (short to ground).
- An unwanted path between two separate circuits (short to power/wire to wire).
- An unwanted path between two parts of a circuit, some of the loads may be bypassed on circuit.
- An unwanted current path inside a component, internal resistance of load too low.

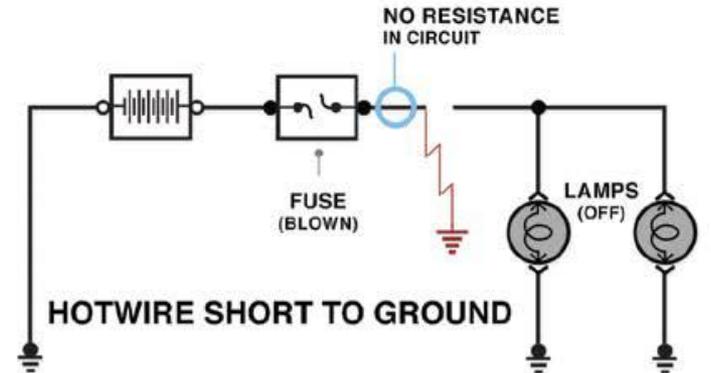
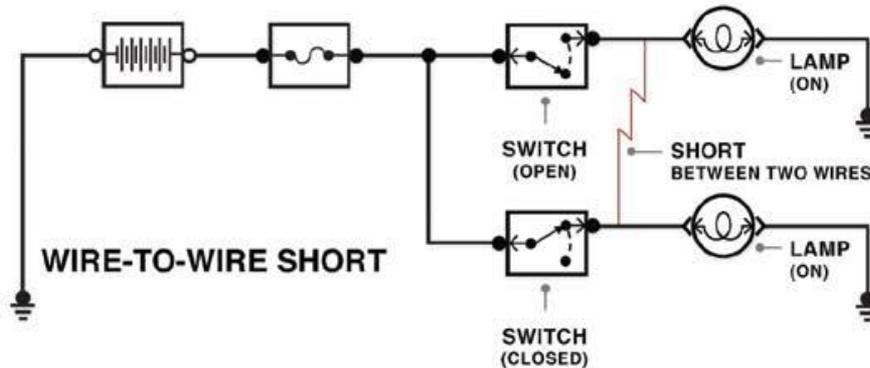
Most common short circuit is short to ground. This short typically blows the circuit fuse or pops the breaker.

Note: It may not be possible to troubleshoot the circuit under its own power.

Short Circuits

In circuits with a short-to-ground or voltage, check for:

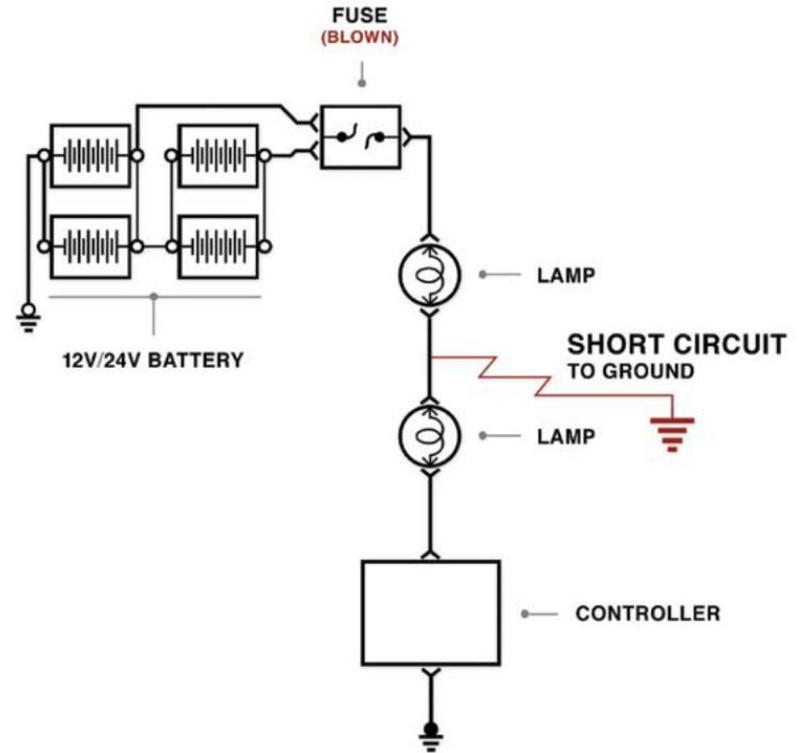
- Previous repairs.
- Physical damage to the harness or vehicle.
- Equipment installed with sheet metal screws that have pierced a harness.



Troubleshooting a Short in Series Circuit

The circuit shown is shorting to ground before the load. The short can be found in one of two ways:

- Checking resistance
- Using an external load

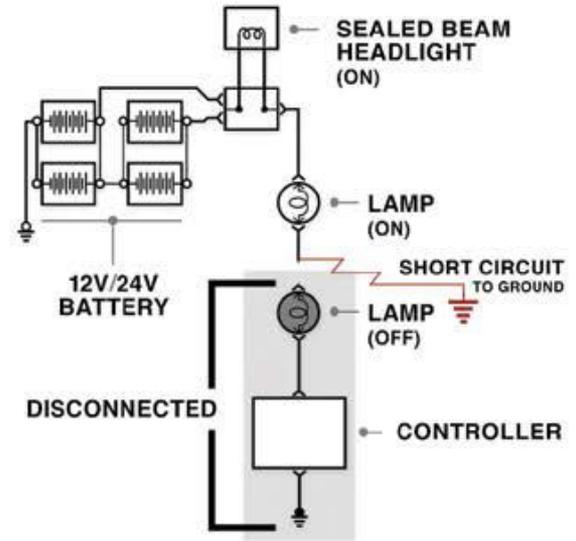
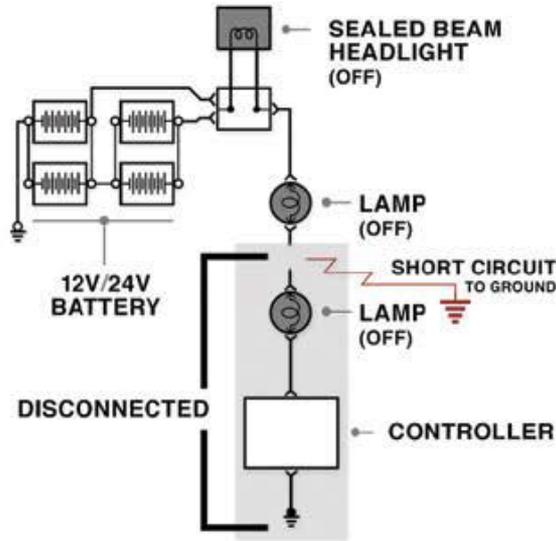
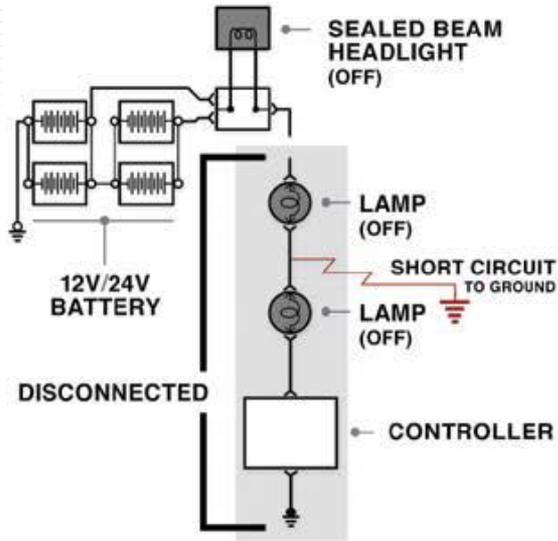


Troubleshooting a Short in Series Circuit – External Load

For some faults, using tools other than a DMM may help diagnose a fault faster. If there is a short to ground in a series circuit, a test light may help you pinpoint the short location.

1. Remove the fuse.
2. Jumper in an external load (a light works well for this).
3. Apply power to the circuit- the light will turn ON.
4. Start by disconnecting the connection point closest to the external load and work your way towards ground.
5. The light will continue to remain lit when you disconnect the section past the short.

Troubleshooting a Short in Series Circuit – External Load



Troubleshooting a Short in Series Circuit – Measuring Resistance

If a circuit has a high resistance, then we could use a DMM to help locate which part of the circuit has the fault. Set the DMM to read Ohms, and then remove all voltage from the circuit by disconnecting the batteries or removing the fuse.

1. Disconnect the connection point closest to the power source.
2. Connect the meter to the connection point closest to the power source and ground.

Note: The measured resistance here should be close to 0Ω . Leave the meter in place.

3. Disconnect the next accessible connection point moving towards ground.
4. The point where continuity is lost is where the short is located.

Unwanted Resistance Circuit Faults

Unwanted resistance in a circuit can prevent it from operating normally.

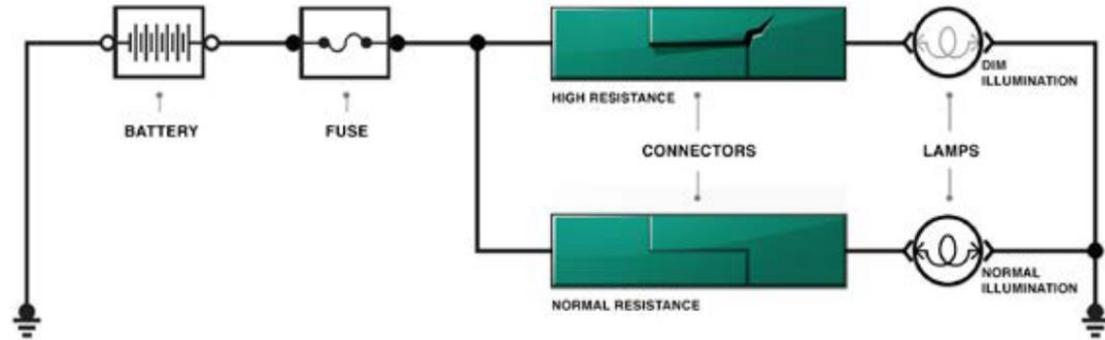
- Unwanted resistance in a circuit can be a poor connection, burned pin, corroded wire / terminal or a faulty component.
- Normal Resistance in a healthy circuit should be very close to 0 ohms using no voltage when the circuit is ON. Higher resistance indicates a possible problem. A dim bulb can be an indicator of high resistance.

This unwanted resistance can best be detected when the circuit is ON by performing voltage drop measurements.

Unwanted Resistance Circuit Fault

Unwanted Resistance Faults cause a load to perform less work than it was intended to and is caused in most cases by:

- Loose or corroded connector
- Improper wiring repair
- Internal wire corrosion
- Defective Load



Note – in a lot of cases unwanted resistance increases as the temperature of the circuit increases during operation.

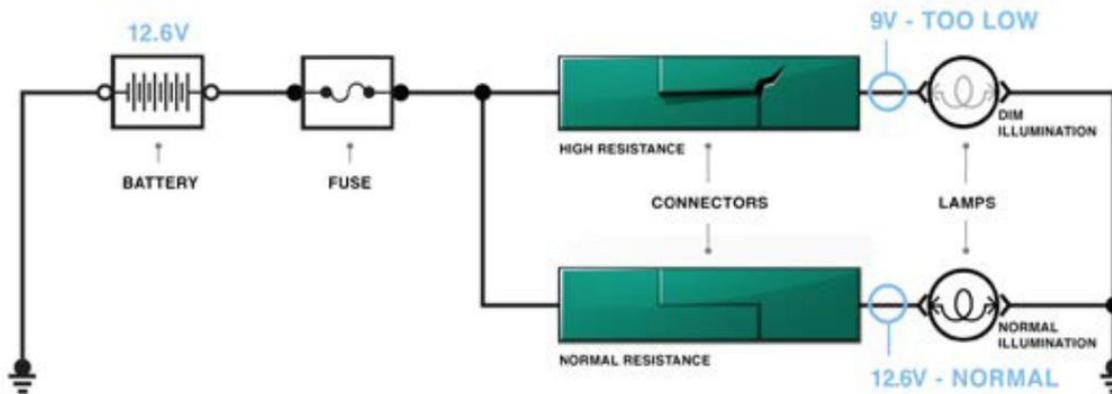
Unwanted Resistance Circuit Fault

The best way to diagnose unwanted resistance faults is by measuring voltage:

Source voltage - this is the voltage measured at the beginning of the circuit.

Available voltage - this is the voltage available to the load.

Load voltage drop - this is the voltage used by the load.



Voltage Drop Measurements

Measuring voltage drop is one of the most useful tests you can perform. A voltage drop test checks for loss of voltage in each portion of the circuit while the circuit is connected, powered and operated.

Note: Voltage drop testing requires you to back probe, all components remain connected during testing.

A voltage drop test is done as follows:

1. Place the positive lead in the most positive section of the circuit you are testing.
2. Place the ground lead on the most negative section of the circuit you are testing.
3. Operate the circuit with the meter leads in place and note the reading.

Remember that voltage dropped is voltage consumed by resistance in the circuit.

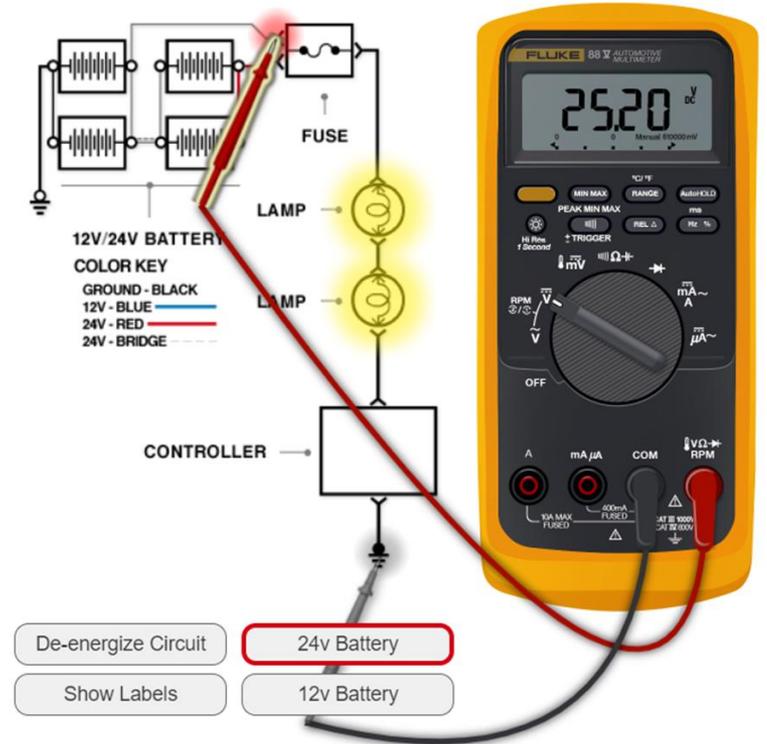
Measuring Source Voltage

This measurement is done at the source of voltage

For the circuit. This could be at:

1. The batteries
2. Fuse Panel
3. Control Module

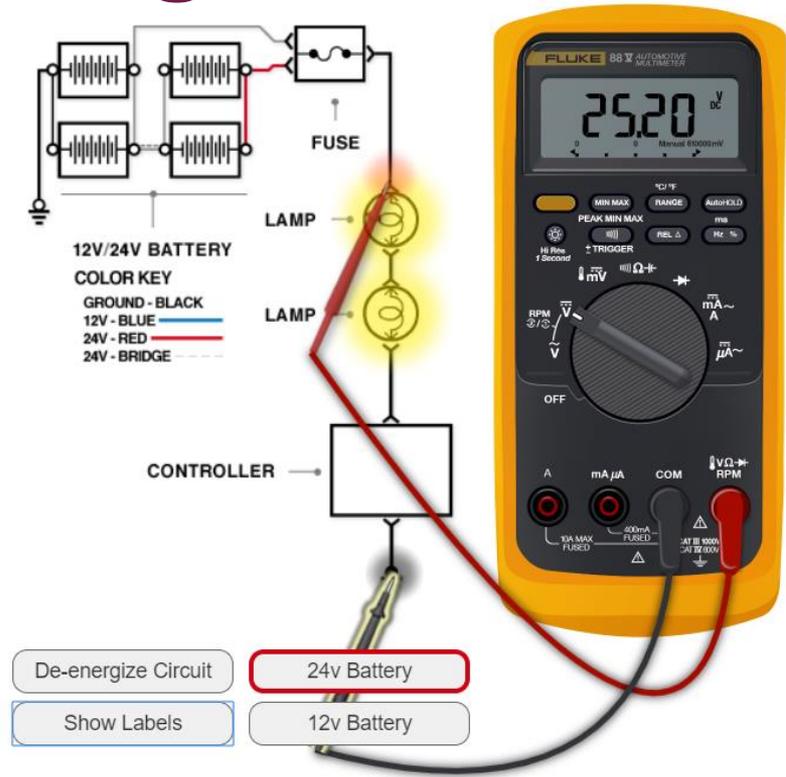
This test is considered voltage drop because you are measuring the drop between the source and ground. Circuit voltage drop should equal source voltage.



Measuring Available Voltage

This measurement is done at the component.

This is the amount of voltage available to the component to operate. This reading should be just under what the source measurement is.

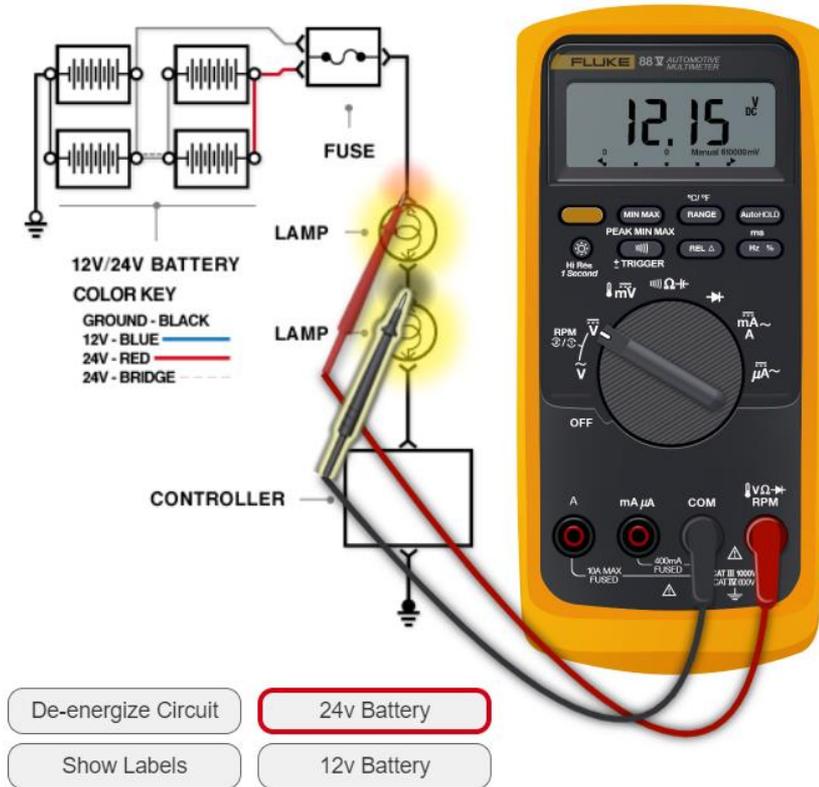


Measuring Voltage Drop

Voltage drop is the amount of voltage consumed by the circuit. Voltage drop of individual components, sections of circuit or connections.

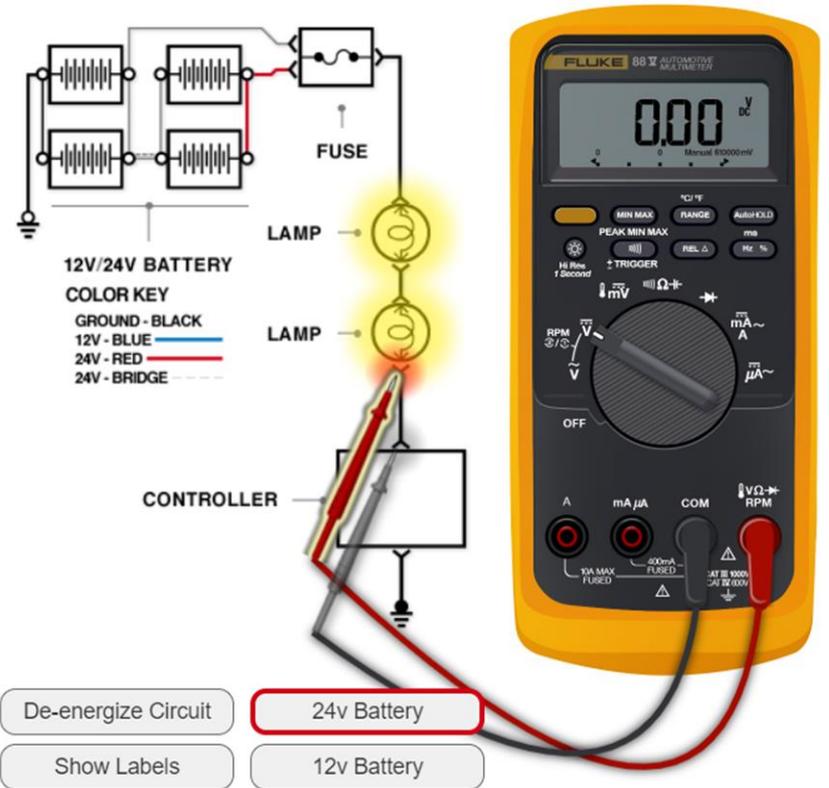
- Voltage drop is voltage consumed.
- Voltage should only drop at the load in a circuit.
- Voltage drop in other areas indicates high resistance.

Voltage should only be used at the loads; voltage used in other areas such as connectors or wiring is unwanted resistance.



Measuring Voltage Drop

Voltage drop thru connections should be minimal – close to 0V.

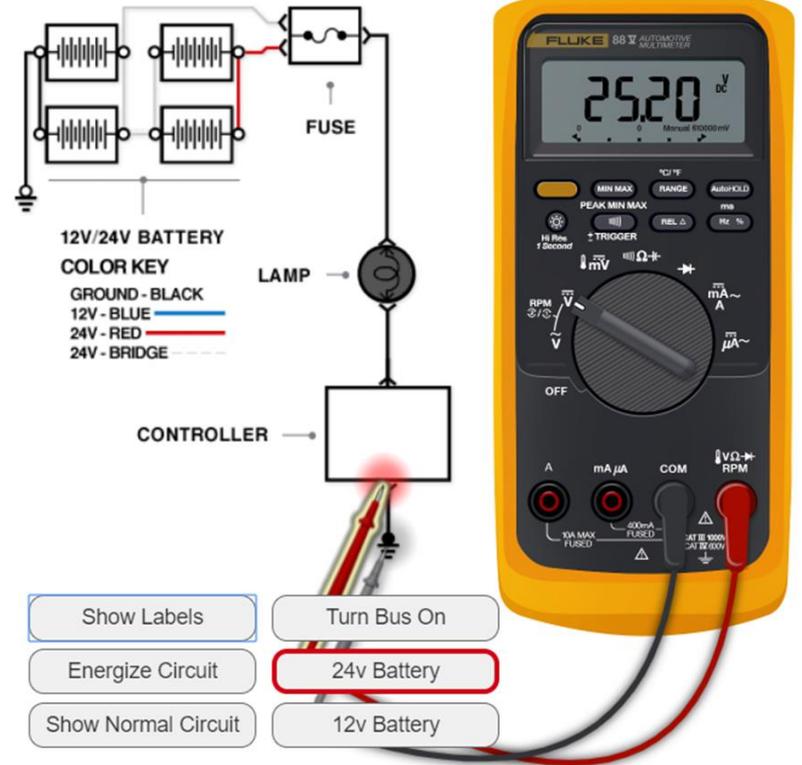


High Resistance on Ground Sample

This sample shows the light is inoperative even though the circuit is ON.

After testing the source voltage, available voltage, and voltage drop of the light the condition was isolated to a faulty ground wire.

As shown by the meter 25.2 volts are being used on the ground side of the circuit not leaving enough voltage for the light bulb to operate.



Avoid Open Circuit Measurements

Before we get started, keep in mind that, when performing voltage measurements, the circuit must be on.

Even though you have heard it, done it, and seen it before, do not disconnect wires to check for voltage.

This is a common mistake; the readings will be open circuit readings. Any resistance in the circuit unless proportionally high in comparison to the meter internal resistance will not be detected.



Open Circuit Reading – Bad Experience

Condition: No Start - Repeat Road Calls.

A mechanic is working on a No Start condition on a Cummins gas engine. During the diagnosis, an active code for throttle plate position sensor low input voltage is found. As part of the diagnostic procedure, the mechanic checks for available voltage to the throttle plate and measures 12.5V. Since there is full battery voltage available to the throttle, the mechanic concludes that the throttle plate is defective and needs replacement. The mechanic replaces the throttle plate, but the **No Start** condition does not go away.

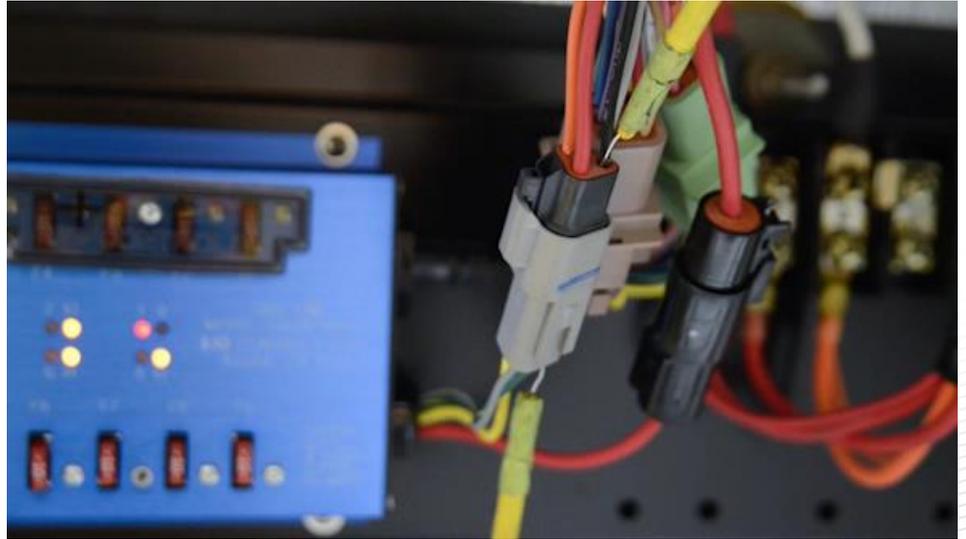
What did the mechanic do wrong? As part of the diagnostic process, the mechanic checked available voltage to the throttle plate and found 12.5 volts. It is here where a serious mistake was made: when the mechanic made the measurement, the throttle plate connector was disconnected. As some of you may know, it is easier to disconnect this component and check it, than it is to back probe it. The reading of 12.5 volts was actually an open circuit reading which did not reflect high resistance in the circuit.

When another mechanic took over the repair, the same diagnostic procedure was performed. This time however, available voltage was checked with the throttle plate connected, and the measured voltage was 3V, indicating high resistance on the supply wire. Further testing revealed a loose connector behind the fuse box. An easy replacement of the connector terminal pins took care of the problem.

So remember, when measuring voltage on any circuit, NEVER OPEN THE CIRCUIT.

Wiggle Test

Intermittent electrical problems are common yet difficult to isolate. The 'wiggle test' will determine if there is an intermittent loose connection or broken wire. Physically move harness and connectors while monitoring the DMM with the circuit operating. Readings should remain constant and should not fluctuate. If readings fluctuate in a certain area, inspect wiring and/or connectors.



Summary

Proper diagnosis of electrical circuits is key to successfully repairing buses the first time.

Remember! All diagnostic tests done correctly will get you to the problem.

Our preference is to perform voltage test whenever possible since the circuit is ON while is being tested. This simulates more closely a real-world situation.

Thank You!

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